The Contribution of Weed Science to Food Production in Great Britain[1]

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Introduction

British Agriculture has existed for at least a thousand years, and it would require a book to record the major developments in weed control. My concern today is with the events of the past 25 years during which weed control has become established as a science, and herbicides have been given a widespread introduction. I hope to set these events against a historical background as they relate to Great Britain, and thereafter, to draw out some thoughts on the impact that modern weed science is making and will make in the future on crop production and land use.

In dealing with this subject, I cannot ignore all the other important developments in agricultural technology which affect the way farmers accept and use weed science. Nor can I ignore the growing trend in Britain that the farming community alone is not the sole arbiter of what may or may not be safe and sensible on the land. The public as a whole casts increasingly questioning eyes toward the practices of modern agriculture.

Weed workers are great travellers, and American and Canadian weed workers are the best travellers of all, as we know to our pleasure and advantage in Britain. But since many of you are unfamiliar with the British farming environment, I propose to devote a few minutes to a very short description of our conditions, emphasizing those aspects which differ from those of much of the American continent.

Great Britain and Its Agriculture

About 55 million people live on a land mass of 94,000 sq miles, which is only about three times the size of Lake Superior. Since many of the hill areas are unsuited to human habitation, the rest of the land is quite crowded. England is the second most densely populated country in Europe.

Topography, climate, and soil. Reference to the contour maps shows that the land varies from flat, low-lying areas in the south and east of England to steep hills that occupy most of Wales and Scotland and parts of northern England. Between these two extremes, much of the landscape is gently undulating. By the standards of the Netherlands, much of the low land is not very low, though drainage is a significant factor in land costs; and by the standards of America or Canada, the highest mountain at 4,400 ft, Ben Nevis, is not very high.

Washed by the warming influences of the Gulf Stream, the climate of Britain is moist and temperate. All along the west coast, the hills collect the rain coming from the Atlantic and the annual precipitation can be up to 60 inches spread fairly uniformly over the year. The further east one goes, the drier is the climate down to 20 inches in Essex or Kent. From the west by the Gulf Stream to the east by the Continent of Europe, the climate becomes less temperate and more continental. A further consequence of the usually frequent rainfall is a lack of sunshine which can affect crop production. At Oxford in central England, we have an annual rainfall of 26 inches spread more or less evenly over the year, and we can hope for a sufficiently high soil temperature to support crop growth during 6½ months of the year.

The great majority of British agriculture occurs on mineral soils that are extremely variable. Coarse or fine sands, silts, chalks, and clays occur in rich variety. There also are small areas of very valuable organic soils. In association with climate and topography, soil type is a decisive factor in the choice of cropping.

Agriculture. As might be expected from the rainfall and the topography, much of western and northern Britain is covered with grass and the major farming interest in these areas is in livestock. In lowland grassland areas, the main livestock products are milk and beef, while in the hills where the climate is less kind, sheep are grazed for the production of wool and lamb, or beef cows produce calves to be sold to the low lands for fattening.

In the drier climate of eastern and southern Britain, arable farming is the main activity, including such crops as wheat, barley, oats, potatoes, sugar beet, and vegetables for processing or for fresh consumption (Table 1).

Table 1. Crops in Great Britain in 1967.

Crop	Million acres
Cereals	9.5
Potatoes	0.7
Sugar beet	0.5
Fodder crops	0.8
Vegetables	0.5
Grassland	18.0
Rough grazing	17.0

Although the arable areas are drier than the grassland, they are not sufficiently dry and hot to permit the production of good quality bread wheats; virtually all the wheat is soft biscuit wheat. Attempts are being made to grow maize in southeast England, but it is only in the best of years that there is enough sunshine to ripen the crop.

Current trends and pressures. During the first half of this century, the circumstances of British farming were dictated largely by competition from overseas produce

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encouraged into Britain by the desire of various governments to import cheap food from an Empire that would buy British machinery in return. Two world wars created temporarily an insatiable demand for home produce. Since World War II, the Empire has gained independence and a substantial change has occurred in the economic circumstances of the British people. The balancing of external trade has become vitally important. Home-produced food is desired because it is a substitute for expenditure on imported food.

Agriculture's reaction to this situation has been conditioned by other pressures. About 30,000 acres of productive land are lost each year to urban development. Other industries attract 20,000 to 30,000 men out of agriculture each year. These numbers may seem small by the standards of the United States, but they are nevertheless significant. In spite of these losses, the gross production of crops and livestock has moved steadily upwards over the past 20 years. The loss of labor has encouraged mechanization. Britain is now the world's largest exporter of agricultural tractors and our agriculture bears the stamp of this mechanization (Figure 1).

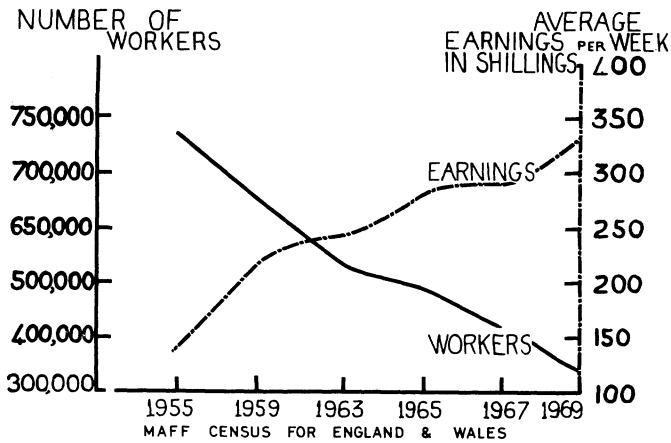

Figure 1. Trends in labor availability and cost.

For some 10 years past, British agriculture has achieved a 7% annual increase in productivity, which is better than the nation's economy as a whole. Now thoughts are turning to Britain's entry into the European Economic Community. What will this mean to British agriculture? Nobody knows. With this short description of Britain and its agriculture, may I now turn to weed control, and first of all the traditional methods.

Weed Control in British Agriculture

Traditional methods. It is a common and understandable failing among research workers to believe that before their wisdom was unleashed on the world, all was darkness, disorder, and confusion. In British agriculture, as well as in other developed agricultures, this was not true of weed control. From the eighteenth century, various forms of weed control had been developed and successfully applied. Traditional weed control hinged on the complementary operation of three measures[3]: (a) the disturbance of the soil by cultivation; (b) the rotation of crops; and (c) the removal of weed seeds from crop seeds.

Until the coming of herbicides, these three were central features of the art of husbandry. Weed control was not their only purpose, but it was the most important. Here, it is relevant to comment on the shortcomings of the first two of these traditional methods. The third (seed cleaning) is still widely used and is regarded as essential.

Soil cultivation for weed control was feasible only when the soil surface was free of a crop, and this usually was the time when weed control was least needed. Once a crop was present on the soil surface, overall cultivation was no longer possible; instead, mechanical hoes could deal with only part of the land and the remainder, particularly the part on which the crop was growing, required the distinguishing power of a man with a hoe. Weed control by cultivation, then, ultimately depended on the plentiful supply of cheap labor that was available up to 1945 but which is now fast disappearing. I believe the tradition of abundant labor is one of the differences between British and American agriculture.

A rotation of crops meant that each year the environment for the weeds would be different and no weed could establish supremacy. If one crop allowed weed seeds to shed, the next would allow the land to be cleaned by hoeing. Implicit in the use of rotation was the need to grow perhaps four or five different crops. When most of the work was done by men capable of switching from one crop to another with equal skill, rotation could be carried out efficiently. Now times have changed. Each crop demands its own mechanization for production, harvesting, storage, and sometimes processing. A fair return on capital requires a certain minimum scale of enterprise. It usually is beyond the pocket of the farmer or the willingness of his bank manager to finance a multiplicity of enterprises. In any event, production processes often are so complex that farmers prefer to specialize on a few crops, and do them well. Rotation suited a farming based on manpower, but does not suit one based on capital-intensive production. Where rotation is still practiced, it is usually in a much simplified form and for reasons other than weed control.

With hindsight, we can now see that the traditional methods of weed control were becoming unsuited to current circumstances of the twentieth century. It would be an intriguing exercise to work out what would have happened if herbicides had not been developed. Happily, they were. From 1945 onwards, chemical industry provided a steadily increasing armory of herbicides, some of American origin, some British, and some European. Regardless of their origin, they came to Britain. The complementary efforts of commercial and state research provided the information upon which safe recommendations could be based. The advisory services and educational establishments adjusted their activities to include the new chemical technology. And last but most important, farmers and growers accepted the new method with enthusiasm.

[3]Weed Control Handbook. 1968. 5th edition, Vol. 1 25. Blackwells Scientific Publication. Oxford, England and Edinburgh, Scotland.

The increase in the use of herbicides in Britain unfortunately has not been systemically recorded; instead, we have to rely on fragmentary evidence and local surveys. I might add that we look with envy at the comprehensive statistics in the United States. In spite of the fragmentary evidence, the trend of herbicide usage in Britain is fairly clear. In the cereal crops, more than 90% of the acreage receives a herbicide application each year. And some fields may receive as many as three separate applications, one for broadleaf weeds, another for annual grasses, and the third after harvest for perennial grasses (6, 8). In many vegetable crops such as peas and carrots, virtually the entire acreage is sprayed every year. In sugar beet in 1969, 85% of the acreage received a herbicide (4). The potato illustrates how quickly farmers can change their methods. The first serious marketing of herbicides for potatoes occurred in 1964; in 1968, 40% of the crop was sprayed, and probably more than half of the acreage will receive a herbicide in 1970[4]. There are at least a dozen approved commercial herbicides for this crop. Similar stories can be told of the fruit industry, of flower, and of ornamental crops.

Wherever and whenever a safe and effective herbicide has been developed at a reasonable price, it has been accepted by farmers and growers. The sole exception has been in grassland. The consequence of farmers' acceptance may be seen in the figures for the growth in the number of herbicides (Figure 2) approved by the Ministry of Agriculture, Fisheries, and Food. In Britain, herbicide sales are greater now than the combined sales of all other pesticide products. British farming, along with its European neighbors, has adopted with enthusiasm this new and revolutionary instrument of weed control.

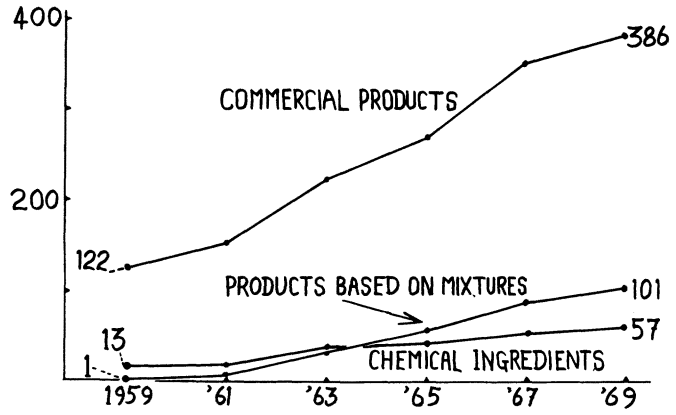

Figure 2. Herbicides approved by the British Ministry of Agriculture for commercial use.

Weed Science, Herbicides, and Crop Production

Unlike the early pioneers of weed science in the United States and Canada during the thirties, the prewar attitude in Great Britain was that weed control was part of the husbandman's art; it was not a subject to be studied in a scientific manner and there were few publications of scientific merit on weed control in British literature. The coming of herbicides changed all that. The pace of chemical discovery and the ascending momentum of the new technology has attracted both scientists and the research funds to support them, with the result that there is now an enormously greater study of weed science. The growth of interest shows in a variety of ways from the European Weed Research Council's publication *Weed Research,* of which Britain is a founder member, to the British Crop Protection Council which is probably best known for its Weed Control Handbook[5] and for its biennial conference which in 1968 attracted more than 1000 delegates, of which about one-third were from overseas and received 1300 pages of papers and research reports. The Weed Research Organization set up on a modest scale in 1960, now has a staff of about 150, and is increasingly establishing itself as the national center for weed research. Herbicides stimulated the growth of weed science in Britain, and now weed science is wider and more embracing than herbicides alone, and it includes all aspects of weeds and their control—biological, mechanical, organizational, and chemical. Important though weed science as a whole is to the efficiency of land use, it is my purpose to consider particularly the consequences of herbicides.

The attributes of herbicides. If selective herbicides were simply a replacement for manual and mechanical hoeing, then presumably the only direct consequence of their introduction would be that hoes would become redundant. But this is not the position. The fact that weed control now can be achieved by a chemical instead of a piece of metal has deep implications, the consequences of which show increasingly in British crop production.

What is it that makes the chemical so different from a hoe? What are the attributes of herbicides that make them so desirable to farmers and which are bringing changes in crop production? I would now like to list them.

1. Herbicides have the power to act on vegetation without soil disturbance. All the traditional direct ways of killing weeds achieved their end by an inevitable disturbance of the soil, by implements, by tractor wheels, or by men's feet. The application of a herbicide from the air or from a wide boom ground crop sprayer can occur virtually without soil disturbance and independent of soil conditions. Because of this we can now examine all those ways in which the past need to disturb the soil for weed control has restricted the freedom of cropping.

2. The power of selectivity associated with a relatively low cost has made efficient weed control possible in low-value crops such as the cereals. For at least 50 years, such crops have been regarded as unsuited to mechanical hoeing and of a value too low to justify manual hoeing. They were regarded as 'dirty' crops to be set in rotation with 'cleaning crops' that permitted hoeing. Almost overnight in the 1950's, herbicides made the dirty crops clean and a major reason for crop rotation disappeared.

[4]Potato Marketing Board. Statistics Branch. 1969.

[5]Weed Research and Weed Control Handbook. Blackwells Scientific Publications. Oxford, England and Edinburgh, Scotland.

3. Herbicides may be applied easily. A modest ground crop sprayer is well within the pocket of the medium or small farmer: it requires little in the way of tractor power and is capable of covering many acres in a days work. The act of spraying requires, therefore, a small initial capital outlay for the sprayer or the tractor and it has extremely low inputs of labor and machinery cost.

4. A fourth attribute relates to the herbicide patent and marketing situation. As the period of patent protection expires, commercial competition operates to the farmers' advantage in either stabilizing price or bringing it down. During a period when practically every other input into British agriculture has moved steadily upwards in price, herbicides have tended to have a descending price structure which, if it continues, can only make them more desirable to farmers.

5. The application of herbicides involves a tendency for some chemical to wander from the target. Be it by dropping onto the soil, by drift, or from discarded containers, the present methods of application on our farms may allow the chemical to affect plants not specifically intended as the target. They also may produce a residue problem in plant or soil.

Herbicides, then, bring selective vegetation control at a low price and on a large scale previously unattainable. In an agriculture which is fast changing from labor abundance to labor scarcity, they open the way to economy of labor. Because they do not require soil disturbance, they encourage a re-appraisal of the practices of soil cultivation and of the ways in which past cropping has had to conform to the requirements of cultivation. Because they get cheaper, new techniques based on herbicides will tend to become more desirable. Let us take some of these thoughts a stage further in three particular farming systems.

Effect on different farming systems.

High value vegetable and processing crops (Mainly east and southeast England). Profound and far-reaching changes have taken place in the production of these crops during the past 15 years. In the days when vegetables were fresh-cut, perishable products with a short life, limitations of transport dictated that they should be grown in proximity to the large city markets, usually on many small holdings. Now the revolution in processing, freezing, and cooling is re-shaping the vegetable industry. Production is moving from the small producers into the hands of large farmers who can provide the necessary scale of operation and expertise. The right soil and climate for the crop, and proximity to the processing plant now dictate the location of the enterprise (5). There is considerable and increasing capital investment in equipment for every stage of production, harvesting, and storage. The sophistication of many of these enterprises now is such that it is unthinkable that they should be put at risk by the interference of weeds. Herbicides are a routine and integral part of the production of these crops; and indeed, it might be claimed that the new systems could not have come about without herbicides.

Although introduced for weed control, herbicides have brought a new freedom to grow many of the crops without soil disturbance after planting. In several crops of which the potato is an example, it has been established that growth can be adversely affected by cultivation once the root system has developed. In such crops, the avoidance of soil disturbance in itself has brought higher yields (7). In other crops such as peas, beans, and carrots, the need for a field lay-out to permit hoeing led to inefficient use of the land (3)[6]. Herbicides in association with modern varieties, and increased plant populations in close rows are leading to higher yields and a better control over the size and quality of the produce, a requirement which is all important in serving an increasingly discriminating public. Food processing in which the United States has led the world is developing fast in Britain now. Herbicides are essential to the new methods of production.

Extensive cereal production. This occurs on soils unsuited to processing crops but where the climate is dry enough to ripen the grain. In the past, there was a marked difference in the form of cereal production in Britain as compared with the Continent of North America. Unlike your large-scale prairie systems, cereals such as wheat and barley occurred on mixed farms growing other crops like potatoes and grass or legumes for feeding to livestock; they were part of the rotational sequence of crops. Three developments have opened the door to large scale and repeated cereal growing in Britain. Nitrogenous fertilizer as a substitute for organic nitrogen; machines such as the combine harvester, which both demand and encourage large scale enterprise; and herbicides as a substitute for crop rotation. With these developments, the way is technically open to large scale prairie farming in Britain. This has happened only to a limited extent because the price of land is high in relation to the earnings from cereals. Nevertheless, grain production has increased considerably. There are areas of England which are largely devoted to cereals, where some farms of 2000 acres or more grow few other crops. Without herbicides, these developments would not have been possible and the home production of grain on the present scale and at the present low price could not have been achieved. The new cereal system has made available a volume of cheap grain for human food and the production of poultry, pork, beef, and dairy products that otherwise would have been imported.

Technical developments in cereal production now are very much affected by the current price trends. Although backed by a certain amount of state support, British grain prices are affected by world prices. In consequence, there has been little price rise for many years past. By contrast, production costs have risen by 17% in the last 4 years (Figure 3).

The cereal farmer is now looking hard for economies in production. The particular relevance of herbicides is in the opportunities that they offer for reduction or modification in the practices of soil cultivation. Over the past 25 years, farmers faced with a dwindling labor force have turned to the engineer for economy in cul-

[6]King, J. M. 1966. Row widths and plant populations in vining peas. The Pea Growing Research Organization. Miscellaneous Publication No. 18.

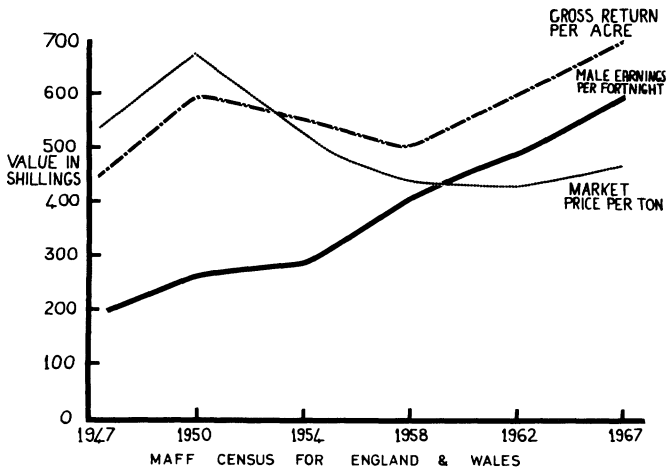

Figure 3. Trends in relative value of barley in England and Wales from 1947 to 1967.

tivation. The engineers' remedy has been to provide more powerful tractors to pull bigger implements but of the same basic types as have been used for about 200 years. There has been little departure from the old conventions of plowing and tilling the soil. With the coming of herbicides, it is now possible to separate weed control from soil cultivation for the sowing of the crop. Indeed, research has followed the principle of the sod-seeder developed in the United States, and is investigating the possibility of growing cereal crops with no soil cultivation, but difficulty is being met in controlling perennial grass weeds by herbicides alone. The most fruitful line of current research on tillage, including that at WRO, is that which is seeking to reduce and simplify cultivation while still providing a reasonable soil environment for germination and early rooting. In Britain as in many other countries, there is now an awakening interest in the physical handling of the soil and there is a growing desire to re-think the whole process of tillage.

Grassland production. The grassland farmers' circumstances are entirely different from the other types of farming. They are usually on land that is too steep and/or wet for easy soil cultivation; their farms often are less well equipped with tractor power than are large arable farms; and they have a limited manpower that should give priority to the livestock. Since World War II, they have been encouraged to plow and resow improved grasses such as perennial ryegrass as a means of increasing livestock output in association with the use of fertilizers. However, the sown swards become substantially infested with weed grasses within 3 to 4 years and are eventually little better botanically than before reseeding (2). The farmers show an increasing reluctance to reseed and settle for indigenous grasses that may not produce so well but do not require sowing. The effort and expense of cultivation for the suppression of the old grass and the sowing of the new is a bar to their benefitting from the products of the plant breeder as do most other sectors of agriculture. Although the seed of improved grasses and fodder crops (Table 2) is relatively cheap, our livestock farms are currently without acceptable techniques for their establishment and therefore for their use.

Table 2. Acreage in thousands of fodder crops in Great Britain.

	1961	1964	1967
Temporary grass	7,002	6,823	5,934
Turnips and swedes	420	355	289
Lucerne	82	63	37
Kale; rape; etc.	518	398	309

Unlike more arid climates where oversowing or sod-seeding may occur in a dry time, grass grows all summer in temperate Britain so that the potential role for herbicides as suppressors is considerable. By destroying the competition of the old sward, they open the way to sowing which can be easy and quick because the new seeds are drilled directly either without disturbance or with only little surface cultivation.

There is considerable current research activity to develop suitable techniques for the various soils and crops. The Weed Research Organization has a long standing interest in this subject dating back to 1956 and the early work in the United States and New Zealand. For many years, our activity was limited to studying the performance of herbicides, but we recently have appointed staff to work on crop establishment as well. The commercial possibilities are being developed by Imperial Chemical Industries Ltd., as a use for paraquat. I understand that about 10,000 acres of fodder crops were direct-drilled in 1968.[7] The prospect that sowing can be made easy without expensive equipment or effort opens up new horizons for the grassland farmer. Instead of the present reliance on perennial plants with their seasonal gluts and deficiencies, he should be able in the future to plan the sowing of plants (both annual and perennial) in productive sequences to meet the requirements of his stock and the availability of labor to harvest.

In addition to their role in sward destruction, herbicides also have a major part to play in controlling the botanical composition of sown and indigenous swards. During the past 7 years at the Weed Research Organization, we have been developing herbicides for their selectivity among grasses. The first of the developments involves dalapon applied at 2 to 3 lb/A in July; that has selectively removed *Agrostis* spp., *Poa* spp., and *Holcus lanatus* (weed grasses) from perennial ryegrass, the preferred crop grass (1).

We can see the potential of exerting a control over pasture composition which is easier, cheaper, and more direct than anything now available. The possibilities for increased livestock production at reduced cost are immense and largely unexplored.

The Contribution of Weed Science to the National Economy

What has been the contribution of weed science to food production in Great Britain? There is no one simple answer to this question in the sense that less weeds led to bigger crops that fed more hungry mouths. Any food deficiencies could and would have been imported, probably in part from the United States and Canada. The answer lies in the changed circumstances of the British

[7]Allen, H. 1968. Private communications.

people and the pressing need to make more efficient use of national resources. The nation has required increased production, but it primarily has required increased productivity. That agriculture could have surrendered one-half million men to other industries since 1945 while itself achieving greater production and greater productivity is due to modern technology in which weed science is the most striking development.[8]

That the British people have been able to gain a steadily rising standard of living, of which cheap food is an integral part, in spite of a fluctuating economic situation has been due at least in part to the increase in production of home food by £1000 m.p.a. since 1950, which would not have been possible without effective weed control.

When the Minister of Agriculture is able to call for increased production of wheat and livestock to offset imports, he speaks to an efficient agriculture fully capable of achieving the targets using production methods based on modern weed science.

The future should see all the present trends accentuated. By 1975, it is forecast that two out of every seven men now on the land will have left[9]. Farms are getting bigger and production methods are getting more sophisticated. Can anyone doubt that a guaranteed freedom from weeds will be important to agriculture in the future? But we must now look beyond the use of land solely for food production.

In a continent as vast as North America, it must be difficult to understand how little room there is in Britain for recreation. As the 97% of the population who do not work in agriculture obtain more leisure, their desire for recreation increases. Covetous eyes will be turned on the countryside. We may be approaching a time when large areas may pass out of agricultural production for recreational purposes. It is unlikely that the natural vegetation climax, which in much of Britain is scrub leading to woodland, will be acceptable to the townsmen; a vegetation control requirement will exist, therefore, which possibly only herbicides will be able to provide economically.

I hope I have said enough to indicate that the role of modern weed science in Britain is a great and expanding one. We can look forward to a continued expansion of chemical use on the land but in a swiftly changing social climate. Public concern for the whole environment is increasing, and correctly so. Many influential public figures in Britain now show an interest in wild life. In 1965, the Natural Environment Research Council was established which has among its interests... 'a better understanding not only of the nature and processes of the environment...but also of their influence on man's activities and welfare and, of growing importance today, of man's influence on them.' I think we all have now to accept that the herbicide honeymoon is over. It has lasted 25 years and every minute has been worth it—ahead lies the long married life between chemical usage and crop production.

Marriage is a life-long relationship, it means the emphasis of all those qualities that make for responsible parenthood, particularly for such bodies as the Weed Science Society of America, the National Weed Committee of Canada, and the British Crop Protection Council which have done so much to develop the new technology. The important qualities will continue to be responsibility, integrity, and discretion. These qualities have nowhere been more evident than in those responsible for weed science, which in most countries has been accepted with little concern by the vast majority of the population. In the future the need for care will be even greater and we must look for ever increasing collaboration between weed workers of all interests. In weed science we have lived long enough to be mature, but we also have the advantage of youth and flexibility; let us try and stay that way.

[8]Her Majesty's Stationery Office. 1968. Agricultures import saving role. Rep. Economic Development Committee for the Agricultural Industry.

[9]Plumb, C. H. 1970. The land with fewer men. Oxford farming Conf. in press.

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